

**The System and Implementation aspects of the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS).** R. L. Jordan<sup>1</sup>, D. Biccari<sup>2</sup>, O. Bombaci<sup>3</sup>, D. Gurnett<sup>4</sup>, W.T.K. Johnson<sup>1</sup>, D. Kirchner<sup>4</sup>, G. Picardi<sup>2</sup>, J. Plaut<sup>1</sup>, A. Safaeinili<sup>1</sup>, R. Seu<sup>2</sup>, K. Wheeler<sup>1</sup> and E. Zampolini<sup>3</sup>.

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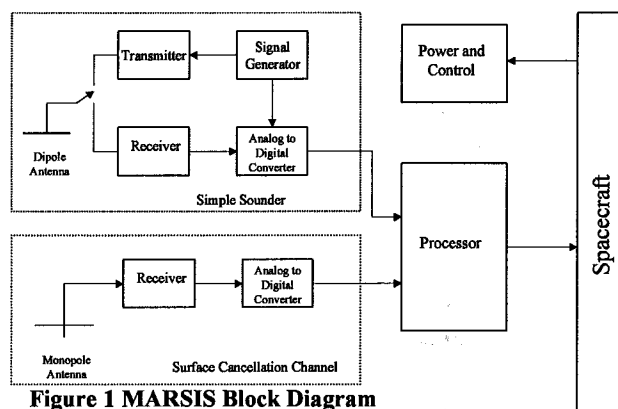
**Introduction:** MARSIS is a radar sounder operating in the HF frequency range to sound the surface of Mars, which will operate from the ESA Mars Express spacecraft [1]. It is scheduled for launch from Baikonour, Russia in June 2003 and arrives in orbit around Mars in early 2004 for a two-year mission. This system is the result of an international collaboration between NASA, the Italian Space Agency (ASI), and European Space Agency (ESA). The MARSIS instrument is a 17 Kilogram total mass sounder consisting of a 40 meter tip-to-tip dipole antenna, a 7 meter long monopole antenna and the electronics module. This design of MARSIS is a tradeoff between the expected penetration into the Martian subsurface that is proportional to the wavelength of the system and the desire to operate at a short wavelength in order to minimize the effects of the ionosphere.

**Instrument Characteristics:** The main objective of MARSIS is to search for water if it exists in liquid form under the surface to a depth of 5 Km. It will also attempt to map and characterize the subsurface geological structure of Mars, which is hidden under a layer of surface dust. In addition to its subsurface exploration goals, MARSIS will study the ionosphere of Mars providing the most extensive amount of data on Martian ionosphere to date. In order to penetrate the Martian surface to a depth of 5 Km, it is necessary to operate at a frequency which is as low as possible consistent with the Martian ionosphere. The instrument de-

method of data acquisition and is separate from the frequencies used for sounding. MARSIS uses 4 frequency bands for sounding the subsurface that have center frequencies of 1.8, 3.0, 4.0 and 5.0 MHz. Operation at each of these bands has a bandwidth of 1 MHz. Operation for the active ionospheric sounding mode covers the 0.1 MHz to 5.5 MHz frequency range. For the subsurface sounding mode of operation, transmission at two simultaneous bands is possible with time displacement used as the method for isolating the returns. Radio signal transmission is through the 40 meter tip-to-tip dipole antenna and as shown in the MARSIS block diagram of Figure 1, echo reception is in both the dipole and monopole antennas. The antenna length is limited by the design of the Mars Express spacecraft. The dipole antenna length is naturally resonant at a frequency of 3 Megahertz. In order to radiate at frequencies other than the resonant frequency, two wideband matching networks are incorporated into the design. The transmitted signal is a nominal 250 micro-second linear frequency swept pulse.

**Instrument Operation:** The MARSIS instrument is designed to operate in an elliptical orbit with a periaapsis of 250 Km and an apoapsis of 10,124 Km. over the Martian surface. The sounder will acquire ionospheric data when the orbiter reaches altitudes below 1200 Km above the Martian surface and subsurface sounding data is acquired when the orbiter altitude is below 800 Km. The selection of the operating frequency band will be made based on the expected local solar zenith angle. For significant penetration of the surface, it is desired to operate at a RF frequency that is as low as possible. The limitations to operating at very low frequencies is the ionosphere of Mars [3,4,5]. The ionosphere of Mars prevents operation at frequencies below 2.5 MHz when the solar zenith angle is less than 80 degrees and at frequencies below 0.5 MHz during nighttime.

An examination of the surface slope distribution from the MOLA laser altimeter indicates that the surface of Mars has a RMS slope of less than 2 degrees with an RMS height distribution of 3 meters for 90 percent of the surface. For a surface with this roughness, the subsurface returns are expected to be stronger than the surface clutter after the planned Doppler fil-



**Figure 1 MARSIS Block Diagram**

sign incorporates 5 separate subsurface sounding modes [2] as well as the active and ionospheric modes. A mode identifies the number of frequencies and

tering. For the remaining 10 percent of the surface of Mars, the surface roughness has a greater slope distribution and a higher RMS height. For these rough areas, the return from the surface clutter is expected to dominate over the subsurface returns. In order to separate the surface returns from the subsurface returns, the MARSIS design incorporates a second receive only channel with an antenna that exhibits a null in the nadir direction. The purpose of this second, or surface clutter cancellation channel is to receive mostly off-nadir surface returns. These surface returns can be subtracted from the returns of the main channel reducing the effects of the surface clutter level. This clutter removal takes place on the ground as both returns from the dipole and clutter cancellation channel are separately sent to the ground. The antenna for the surface cancellation channel consists of a 7-meter monopole. The receive channel electronics after the antenna is identical to the subsurface sounding channel.

Each of the two receiver channels has first RF amplification prior to down conversion to an intermediate frequency of 0.7 Megahertz. The returns are filtered in their native frequency range and subsequently at the intermediate frequency. The receivers have a range of gain between 33 and 73 dB prior to conversion to a digital format by an 8 bit A/D converter. The data are first buffered prior to transmission to the data processor. The digital processing section can take a portion of the digital data in an unprocessed form for telemetry to the ground or it can process the return echos in a dual DSP processor.

The control of the MARSIS instrument is via an Operation Sequence Table (OST) which contains all the necessary control parameters for a data pass. It is possible to command the instrument in approximately 1 second intervals. This OST is calculated on the ground and telemetered to the Mars Express Spacecraft prior to each orbital pass.

**Data Processing:** The subsurface sounder operates at a nominal pulse repetition rate of 130 pulses per second and acquires sounding data in blocks of approximately 1 second in duration. If the sounder is operating at a frequency close to the local plasma frequency, the return signal from the surface is expected to be dispersed and attenuated by the ionosphere to a level inversely proportional to the instantaneous frequency. The return echos are converted to digital form at a rate of 2.8 Megasamples per second and a duration of 350 microseconds. The return echos for a block of data (approximately 1 second duration) is then coherently integrated in the on-board digital processor prior to telemetry to Earth. Depending on the mode selected, the data may be combined from separate doppler filters

to form multilook data or the returns from a single doppler filter returned to the ground. The data returned are in the frequency domain in order to reduce computation demands on the processor and data volume per block of data. These data contain the dispersion effects of the ionosphere and this phase distortion is detected from the front surface reflection. The effects of the ionospheric distortion are then removed from the sounder data on the ground.

#### References:

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